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Injury Reconstruction: The Biomechanical Analysis of Accidental Injury

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ABSTRACT

Injury reconstruction is a process of injury analysis which combines both medical and engineering technology to produce a composite picture of injury causation. The process is outlined and the potential applications of this analysis are detailed.

Injury reconstruction is a method of analyzing an accident and resulting injuries to produce a comprehensive description of the injuries in both medical and engineering terms which reflect the injury and associated causative factors. The steps in this process are outlined in Figure 1.

The sources of information for defining injury (Table 1) are the medical records, x-rays, patient photographs, and descriptions of the injuries by the patient and other observers. All medical records which reflect the acute injuries sustained at the time of the accident should be reviewed. This includes an analysis of the x-rays independent of interpretations in the medical records. The medical records of all occupants of the vehicle should be reviewed. The presence of similar injuries can confirm the injury mechanisms. The absence of similar injuries may provide clues to such differences as seating position or the use or non-use of restraints. The medical records may also contain information about the pre-existing medical conditions which can affect the tolerance to injury such as osteoporosis or degenerative spine disease. A history and documentation of prior trauma can also eliminate potentially confusing injury data.

Injuries are described in anatomic, physiologic, and pathologic terms (Table 2) to reflect the nature, location, and severity of the injury. Severity indices in both regional and whole body terms can be useful particularly when there is a need to access injury databases.

Steps 2 and 3 in the flow diagram can be performed in varying order but must necessarily serve as cross-checks on each other.

The vehicle kinematics including the principal direction of force and delta-V for each of the relevant vehicle motions are derived from an analysis of the police report, exam of the accident scene and vehicle(s), and observations of

FIGURE 1. INJURY RECONSTRUCTION: FLOW DIAGRAM

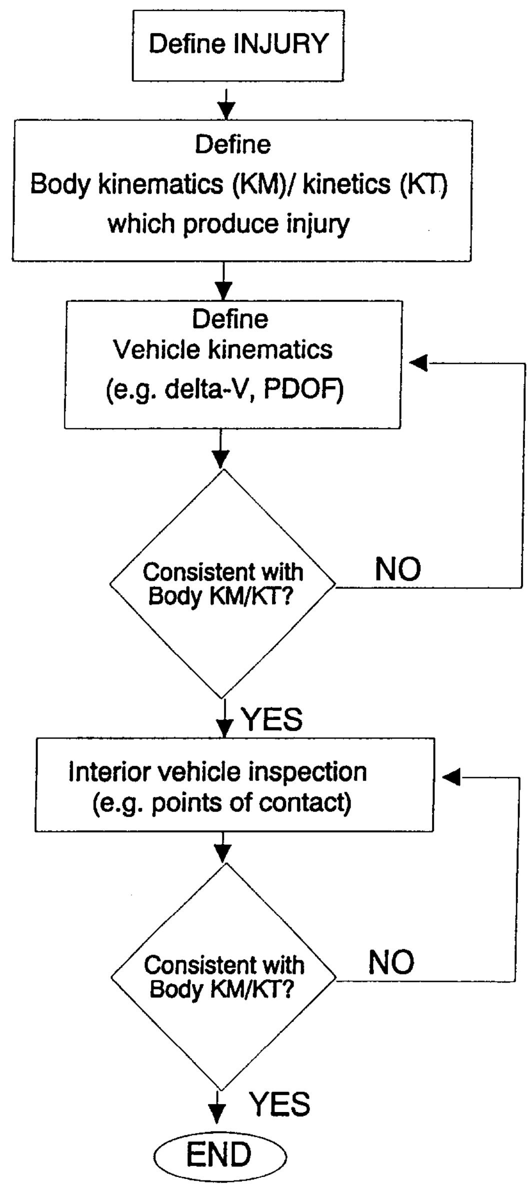


TABLE 1. DATA NECESSARY FOR INJURY RECONSTRUCTION

DATA	SOURCES
Comprehensive description of all injuries of all vehicle occupants (injury type, location, severity)	Accident vehicle(s) Medical records (including physician, nursing, and EMT caregivers) and x-rays Interviews with vehicle occupant(s) and other witnesses
Location and description of areas contacted within and exterior to vehicle (matched to specific injuries for each occupant); forensic data confirming occupant contact and location	Accident vehicle(s) Accident scene (ground/pavement and other environmental objects, e.g., trees, fences, other vehicles) Interviews
Human tolerance data	Experimental data on human tolerance
Restraint system: use and functional characteristics	Accident vehicle(s) Interviews
Vehicle kinematics and kinetics; prinicipal direction of force (PDOF) and velocity change (delta-V) for all significant vehicle motions	Accident vehicle(s) Accident scene Numerical calculations Interviews

TABLE 2. MEDICAL DESCRIPTORS

I. TYPE
(e.g., contusion, laceration, abrasion, rupture, fracture, hemorrhage, edema, ecchymosis)

II. LOCATION
- a. Surface (skin)
- b. Hard and supporting tissues (e.g., bone, ligament, tendon)
- c. Organs (e.g., intestine, liver, spleen, kidney)
- d. Central nervous system (e.g., brain, spinal cord)

III. SEVERITY
- a. Injury scales
- b. Other descriptors (e.g., dimension, open, closed, comminuted)

IV. History and documentation of prior injuries and pre-existing medical conditions

accident witnesses (Table 1).

The occupant kinematics are influenced by the kinematics of the vehicle. Further confirmation comes from a correlation of injuries with an inspection of the vehicle. Occupant kinetics include the force, force direction, and method of application. This is derived from the injuries, the vehicle kinematics, and known human tolerance levels.

Some of the key tolerance information can be summarized as follows:

FACE - Injuries to the face can be divided into soft tissue and bony categories. The mechanical properties of the skin are well summarized by Haut[1]. Clues to force direction and object contacted can be suggested by shape and depth of an injury. For example, road abrasions tend to be deeper, more distributed from tumbling and have particulate foreign bodies embedded. Abrasions from interior contacts are related to the surface characteristics of the contact, as well as the clothing worn. Lacerations may occur either from sharp penetration, e.g., sharp exposed edges, or excessive tension. The shape of the laceration and strain necessary to produce it (Figure 2) will

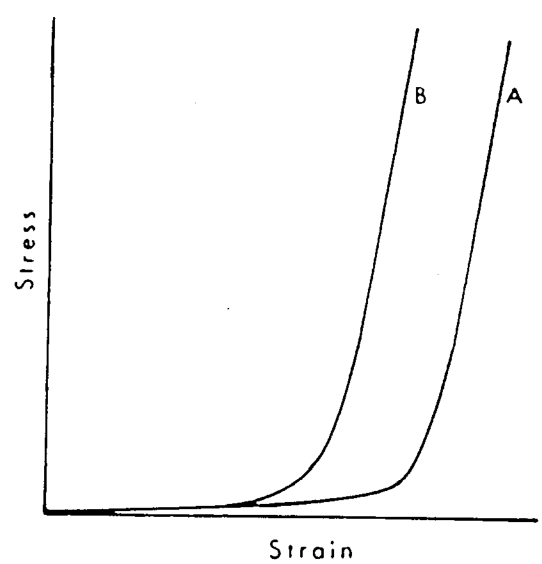


FIGURE 2. Effect of specimen orientation on the tensile response of skin. A = specimen taken parallel to craniocaudal axis; B = specimen taken perpendicular to the craniocaudal axis. (From Daly.[2])

vary according to its orientation to the relaxed skin lines (Figure 3). Lacerations from sharp edges will match the resulting skin defect while failures in tension will occur from forces applied at an angle to the long axis of the tear. The depth, edge characteristics, e.g. sharp or jagged, and presence of foreign materials will also suggest the contact surface. Trapdoor lacerations clearly point to the direction in which the force was applied.

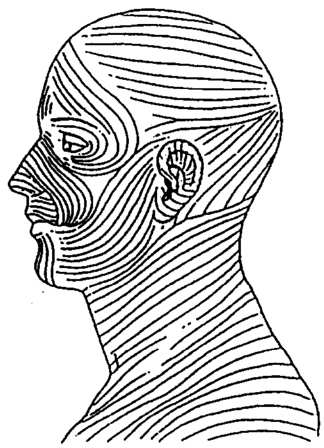


FIGURE 3. Schematic showing the lines of skin cleavage -- Langer's Lines.

Facial bone fractures have been characterized in several ways. Schneider[3] (Table 3) reported on fracture tolerance levels with an impactor surface of 1 to 5 square inches (6.5 to 33.2 cm^2), while Nyquist[4] presented data (Figure 4) using impactors which measured penetration vs. force over larger areas of the face. These results along with those of others (Allsop[5]) permit correlations between the impact tolerance of a particular facial bone or region and the observed injury. Thus, a particular fracture pattern suggests the geometry and forces necessary to produce a particular injury. For example, an isolated fracture of the body of the zygoma (i.e., the cheekbone) with overlying soft tissue edema and bruising suggests contact with a blunt partially compressible surface with a force of 283-583 pounds (1259 - 2594N) applied in a frontal or fronto-lateral direction that does not exceed the anatomic boundaries of the zygoma (Table 3).

It is necessary to distinguish between fractures due to a direct force application and those at a distance from the force application. An example would be fractures of the orbital floor due to a force application to the body of the zygoma.

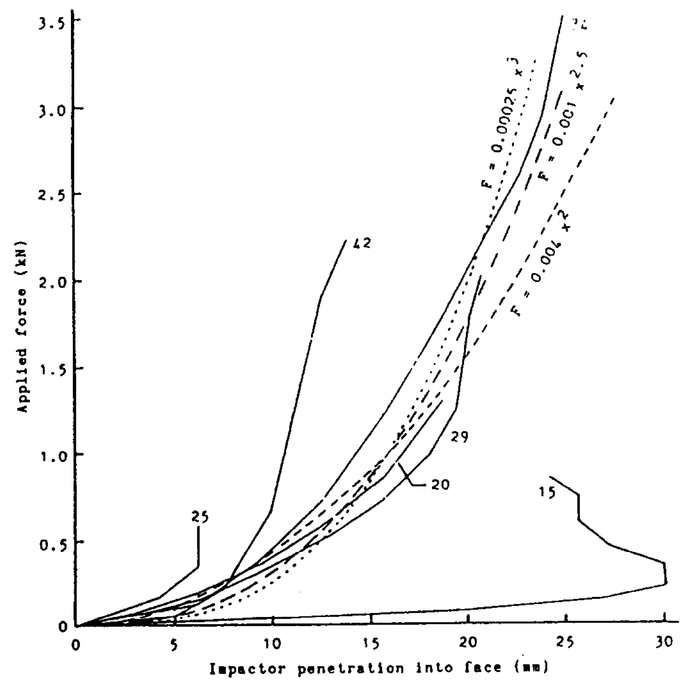


FIGURE 4. Force vs. penetration for tests 15, 20, 25, 29, 34, 42. Best fit: force (kN) = (0.001) (penetration mm)$^{2.5}$. (From Nyquist et al., 1986. Reprinted with permission from Society of Automotive Engineers, Inc.)

TABLE 3. FACIAL BONE IMPACT TOLERANCE (From Schneider.)

		Fracture Forces					
	Impactor Area	Mean		Range		Sample	
Bone	cm^2 (in^2)	N	(Pounds)	N	(Pounds)	Size	Reference
Zygoma	6.5 (1.0)	2594	(583)	614–3470	(138–780)	29	16, 17
Zygoma	6.5 (1.0)	1259	(283)	845–1665	(190–374)	5	14
Zygoma	33.2 (5.2)	2297	(516)	1600–3360	(360–756)	7	14
Zygomatic arch	6.5 (1.0)	1535	(345)	925–2110	(208–475)	17	17
Maxilla	6.5 (1.0)	1148	(258)	623–1980	(140–445)	13	17
Mandible							
Midsymphysis	6.5 (1.0)	3100	(697)	1890–4110	(425–925)	9	17
Lateral	25.8 (4.0)	1918	(431)	818–3405	(184–765)	9	17
Frontal	6.5 (1.0)	5287	(1188)	2670–9880	(600–2220)	31	16, 17

SPINE - The most common failure mode of the spine is in compression with flexion. McElhaney[6] studied the load deflection characteristics of the cervical spine in terms of rate sensitivity (Figure 5) and showed a typical load to failure with compression (Figure 6). Since injury to the cervical spine requires a unique alignment of head, neck and torso, McElhaney studied the effects of various constraint situations, as well (Figure 7). Various studies have focused on axial load to failure with ranges of 1720 +/- 1230N for bilateral facet dislocations (a flexion-compression injury) to 4810 +/- 1290N to 5970 +/- 1049N for other compression studies.

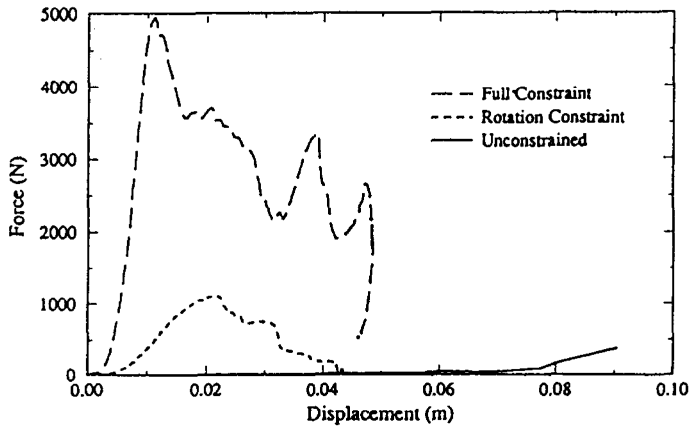


FIGURE 7. Force-deflection behavior to failure for three cervical spines, showing the influence of end condition on axial stiffness. (From McElhaney.)

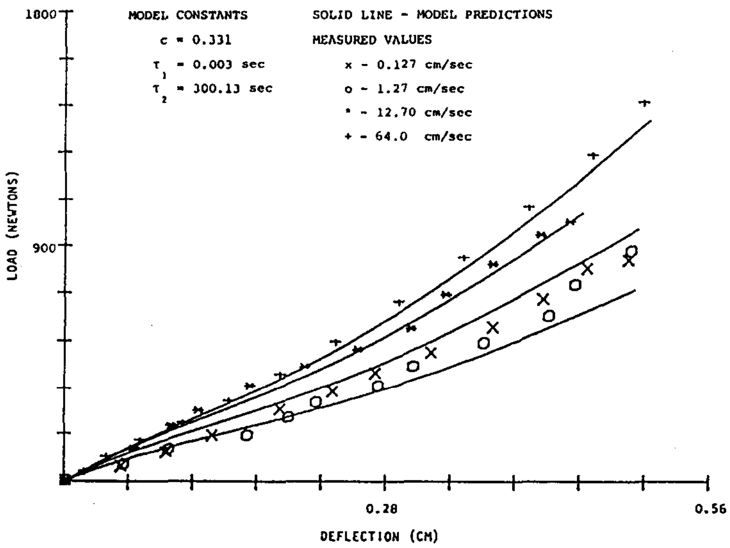


FIGURE 5. Rate sensitivity of cervical spine in compression. (From McElhaney.)

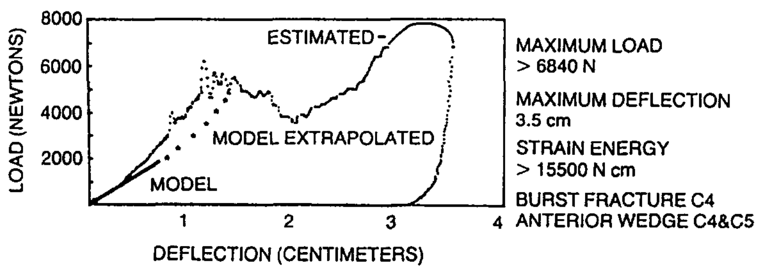


FIGURE 6. Compression load vs. deflection of human cadaveric cervical spine. (From McElhaney.)

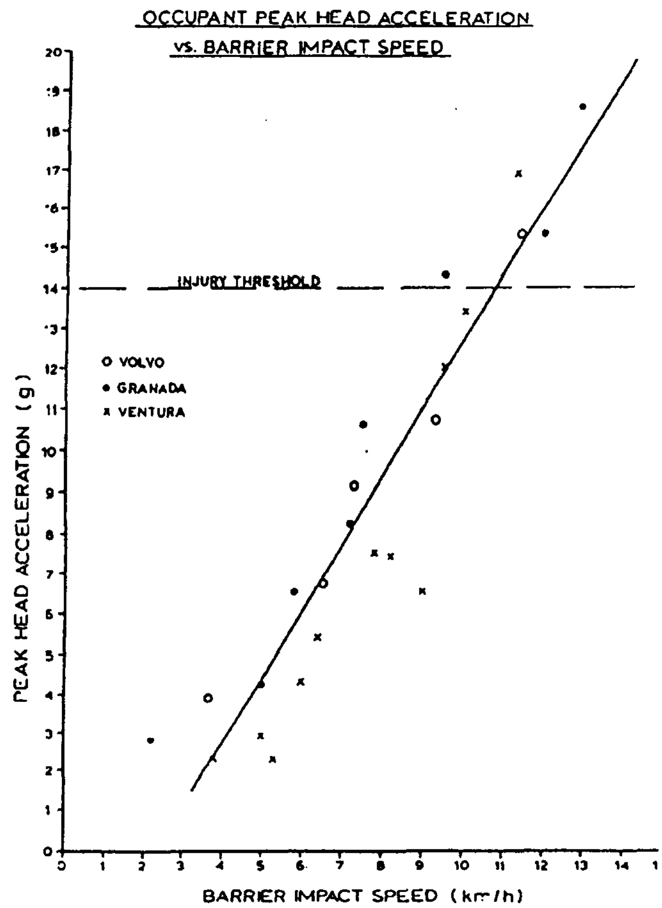


FIGURE 8. Graph showing the peak head acceleration in the sagittal plane as a function of barrier impact speed. (From West et al.)

Soft tissue responses of the neck, e.g., discs, ligaments, muscles, have been studied with reference to dynamic ranges of motion. West[7] used human volunteers in a series of rear end collisions to quantify the relationship between barrier impact speed and peak head acceleration and related this to an injury threshold (Figure 8). This was based on earlier work by Mertz[8] which suggested a hyperextension injury level based upon rotation of the head in relation to the torso by measuring the moment at the occipital condyles (Figure 9).

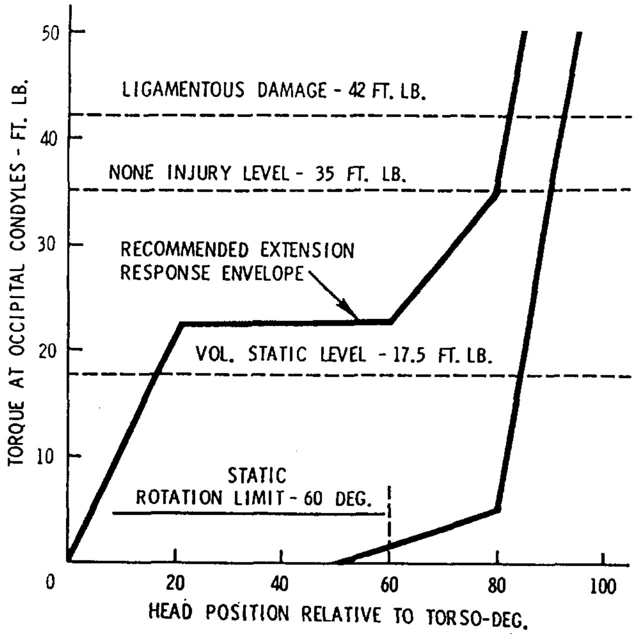


FIGURE 9. Head-neck response envelope for extension and various tolerance levels. (From Mertz et al., 1971. Reprinted with permission from Society of Automotive Engineers, Inc.)

CHEST - Cavanaugh[9] reviewed thoracic trauma suggesting probability of thoracic AIS of 3 or greater based on the viscous criterion (Figure 10). Other criteria used have been force deflection, both for anterior and lateral impacts (Figure 11).

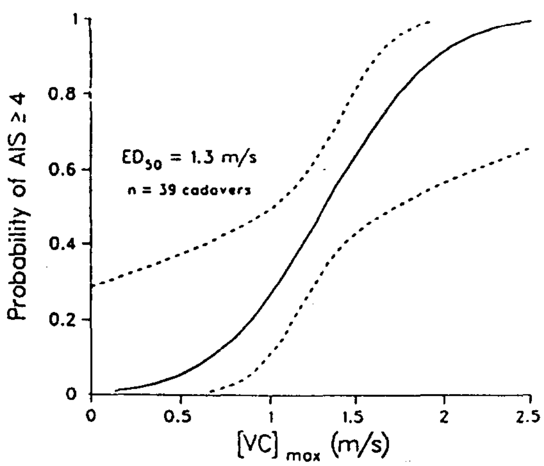


FIGURE 10. Curve showing the probability of thoracic AIS >3 as a function of VC_{max}. These data were derived from unembalmed cadaver impacts run at University of California, San Diego. (From Viano and Lau[10], 1986. Reprinted with permission from Society of Automotive Engineers, Inc.)

Localized impacts will tend to produce local rib fractures with possible penetration of the thorax. More commonly, a well distributed load produces rib fractures with lung contusion and laceration possible, the latter occurring either due to penetration by broken ribs or to the decelerative forces. Because of the unique geometry of the ribs, fractures can occur adjacent to or distant from the applied load. Forces applied to the sternum or the spine produce a distinct pattern of fracture occurring at the costo-chondral or costo-vertebral junctions where the rib articulations are located. Most chest impacts occur from contacts with steering wheel, doors, and instrument panel. The forces necessary to produce injury will suggest chest acceleration and impact location possibilities.

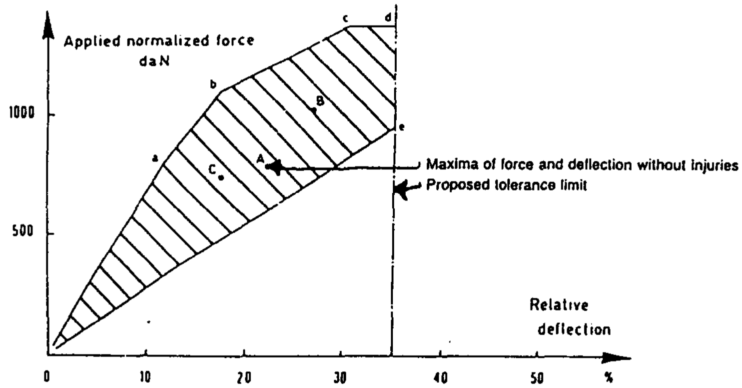


FIGURE 11. Normalized force vs. deflection corridor based on a series of lateral drop tests with unembalmed cadavers. (From Stalnaker et al.[11], 1979. Reprinted with permission from Society of Automotive Engineers, Inc.)

ABDOMEN - Rouhana[12] reviewed data in which rigid impactors, drop tests and a lap belt impactor have been used to characterize the responses of the abdomen to imposed forces (Figures 12-14). The problem of characterizing blunt forces is the wide discrepancy between the tolerance levels and exposure of the various intra-abdominal organs. For example, the spleen has the lowest tolerance level, but is partially shielded by the lower rib cage. The intestines may vary in tolerance depending

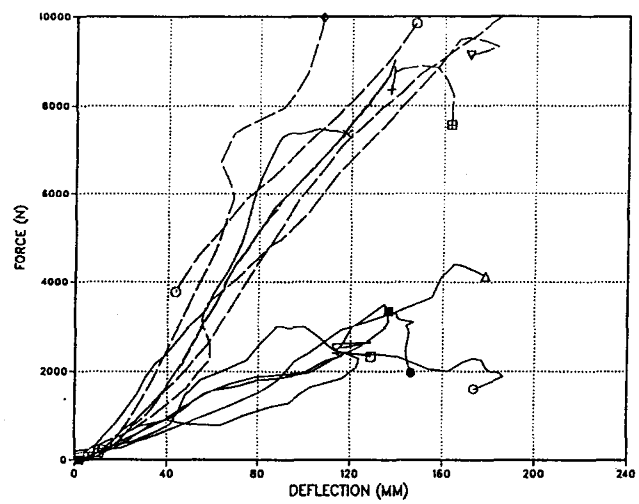


FIGURE 12. Rigid impactor, frontal response of the lower abdomen. (From Cavanaugh et al.[13], 1986. Reprinted with permission from Society of Automotive Engineers, Inc.)

upon the degree of tethering of a particular segment. Intraluminal pressures at the time of impact may also play a role. Criteria such as peak force, compression, viscous criterion, velocity and energy have been evaluated. The liver, spleen and mesentery are most susceptible to injury by local forces.

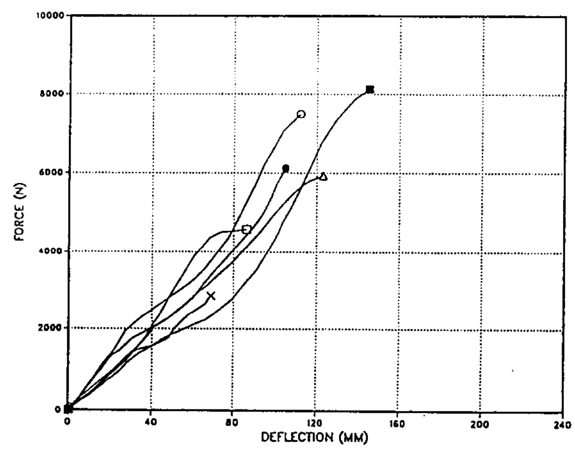


FIGURE 13. Rigid impactor, frontal response of the lower abdomen. (From Nusholtz et al.[14])

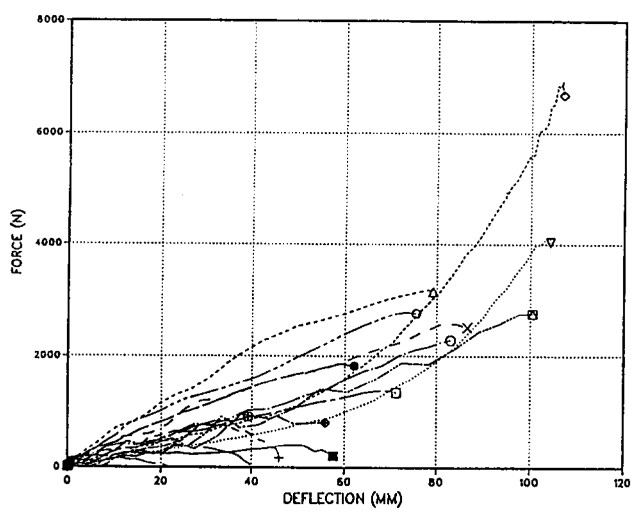


FIGURE 14. Lap belt impactor, frontal response of the lower abdomen. (From Rouhana et al.[15], 1989. Reprinted with permission from Society of Automotive Engineers, Inc.)

SOFT TISSUES - The properties of soft tissues (Figure 15) are of importance when considering injury to the spine and other joints. The load/deformation relationship is modified (Figure 16) by the time dependency created by vehicular accident situations. The tolerance levels (Table 4) reflect a wide variation between yielding and non-yielding structures. Damage to these tissues is a reflection of the force/time history of the injured area, as seen within the context of the overall collision force/time history.

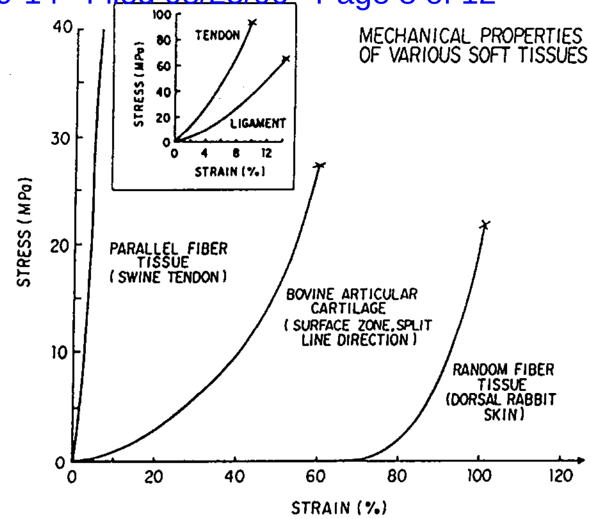


FIGURE 15. Typical stress-strain curves for various soft tissues. (From Woo et al.[16])

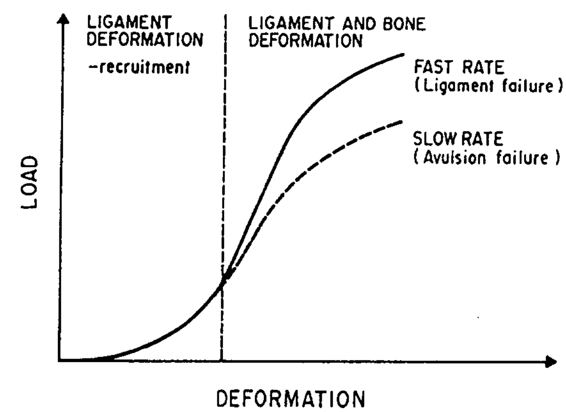


FIGURE 16. Curves showing the effect of different loading rates on the load-deformation behavior and the failure modes of a bone-ligament-bone complex. (From Woo et al.[16])

Tissues (In Order of ↑ Strength)	Ultimate Stress (mPa)	Ultimate Strain (%)
Muscle'		
Noncontracted	0.1–0.3	40–60
Ligament'		
Elastic (nuchae)	1–2	30–125
Bone (cancellous)	1–2	0.1
Tension	1.5–2	0.03–0.6
Compression		
Fascia'	15	15–17
Cartilage (hyaline)		
Tension	1–40	10–100
Compression	7–23	3–17
Shear	6	—
Cartilage (fibrocartilage)		
Tension	10–50	10–20
Compression	20	30
Tendon'	40–100	10–17
Collateral ligaments'		
Nonelastic	60–100	5–14
Bone (cortical)		
Tension	90–170	0.7–5
Compression	100–280	1–2.4
Shear	50–100	—

*All values are approximate and based only on specific test conditions.
'Tension only.

TABLE 4. PROPERTIES OF VARIOUS MUSCULOSKELETAL TISSUES* (From Frank and Woo.[17])

BONE - The failure patterns of bone reflect both the tolerance level and force applied. Fracture patterns (Figure 17) can reflect the manner in which the force was applied. For example, a torsional injury might occur when the foot is fixed and the lower leg is forcibly rotated. Both strain rate (Figure 18) and direction of applied stress (Figure 19) influence the likelihood of injury. Tolerance levels for various bone failure modes (Tables 5-9) are the ultimate determinants of whether failure will occur.

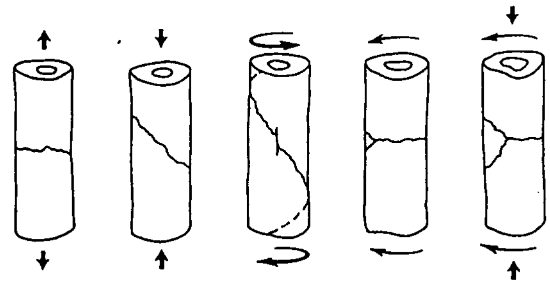


FIGURE 17. Fracture patterns created on cortical bone due to tension, compressive, torsional bending and combined bending and compressive forces. (From Carter and Spengler.[18])

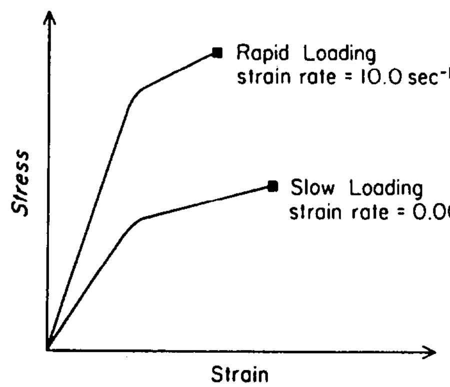


FIGURE 18. The influence of strain rate on the stress-strain characteristics of bone tissue. (From Carter and Spengler.[18])

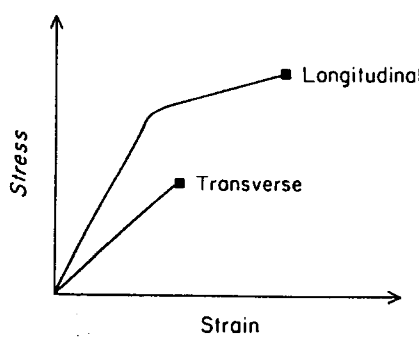


FIGURE 19. The influence of the direction of the applied stress on the stress-strain characteristic of bone tissue. (From Carter and Spengler.[18])

TABLE 5. Failure torques due to torsion about the bone axis. (After Messerer[19], in Melvin.[20])

	Clavicle	Humerus	Radius	Ulna	Femur	Tibia	Fibula
Male, N·m	15	70	22	14	175	89	9
	(12–17)	(55–78)	(16–27)	(8–21)	(141–222)	(63–110)	(6–12)
Female, N·m	10	55	17	11	136	56	10
	(8–11)	(39–80)	(13–23)	(9–13)	(78–207)	(47–63)	(8–16)

TABLE 6. Transverse crushing loads for direct compression of the shafts of bones. (After Messerer[19], in Melvin.[20])

	Humerus	Radius	Ulna	Femur	Tibia	Fibula
31-year-old male, kN	8.33	5.15	5.39	12.74	5.88	2.95
24-year-old female, kN	5.88	3.83	3.04	10.78	6.37	3.04

TABLE 7. Failure loads for compression along the bone axis. (After Messerer[19], in Melvin.[20])

	Clavicle	Humerus (End Failures)	Radius	Ulna
Male, kN	1.89	4.98	3.28	2.21
	(1.22–2.64)	(2.15–7.83)	(2.35–4.21)	(1.76–2.84)
Female, kN	1.24	3.61	2.16	12.93
	(0.88–2.06)	(2.45–5.09)	(1.03–3.18)	(0.88–1.71)
	Femur (Shaft Failures)	**Femur (Neck Failures)**	**Tibia**	**Fibula**
Male, kN	7.72	27.99	10.36	0.60
	(6.85–8.56)	(6.85–10.52)	(7.05–16.39)	(0.24–0.88)
Female, kN	7.11	4.96	7.49	0.48
	(5.63–8.56)	(3.91–5.81)	(4.89–10.37)	(0.20–0.83)

TABLE 8. Fracture loads due to bending (kN). (From Yamada.[21])

Bone	Age Groups: *20–39 Yrs*	*40–49 Yr*	*50–59 Yr*	*60–69 Yr*	*70–89 Yr*	Adult Average
Femur	2.72±0.11	2.47±0.05	2.35±0.09	2.33±0.06	2.14±0.11	2.45
Tibia	2.90±0.11	2.52±0.11	2.43±0.05	2.39±0.09	2.29±0.09	2.60
Fibula	0.44±0.02	0.40±0.04	0.39±0.03	0.37±0.02	0.33±0.02	0.39
Humerus	1.48±0.12	1.39±0.10	1.28±0.10	1.23±0.09	1.13±0.08	1.33
Radius	0.59±0.07	0.53±0.04	0.52±0.08	0.48±0.04	0.43±0.03	0.52
Ulna	0.71±0.05	0.63±0.08	0.61±0.06	0.59±0.04	0.55±0.04	0.63

TABLE 9. Fracture loads due to bending. (After Messerer[19], in Melvin.[20])

	Clavicle	Humerus	Radius	Ulna	Femur	Tibia	Fibula
Male, kN	0.98	2.71	1.20	1.23	3.92	3.36	0.44
	(0.78–1.18)	(2.35–2.94)	(0.98–1.77)	(0.98–2.16)	(3.43–4.66)	(2.30–4.90)	(0.35–0.54)
Average support length, cm	12	22.4	16	16	31.7	24.7	24.7
Average maximum moment, N·m	30	151	48	49	310	207	27
Female, kN	0.60	1.71	0.67	0.81	2.58	2.24	0.30
	(0.49–0.69)	(1.18–2.35)	(0.54–0.88)	(0.69–0.98)	(2.26–3.33)	(1.86–2.65)	(0.21–0.39)
Average support length, cm	11.5	20	14	14	28	22.2	22.3
Average maximum moment, N·m	17	85	23	28	180	124	17

EXAMPLE - The following illustrates how a biomechanical analysis could be performed using tolerance data.

If the medical reports and x-rays define a "butterfly" fracture of the proximal tibia (i.e. the "shin" bone), then both the biomechanical and clinical literature would indicate that this was due to an anteriorly applied impact load which caused a 3-point bending of the bone (Figure 20). If one assumes for this example that the load was applied approximately one-third the bone's length from the tibial plateau, the load exerted by the body laterally to the top of the tibia can be calculated to be two-thirds the impact load (Figure 21). Using human tolerance data[22], a dynamic load of 1140 pounds or 5078N can cause failure of the tibia. This would mean that a man weighing 150 pounds or 668N would have to experience a deceleration of approximately 5 g's to cause a load sufficient enough to break the bone. Knowing this, the accident reconstruction would have to determine a delta-V which could cause this deceleration and a PDOF which would reflect essentially a head-on collision. Finally, the inspection of the vehicle's interior would most likely demonstrate contact areas in the lower area of the dashboard.

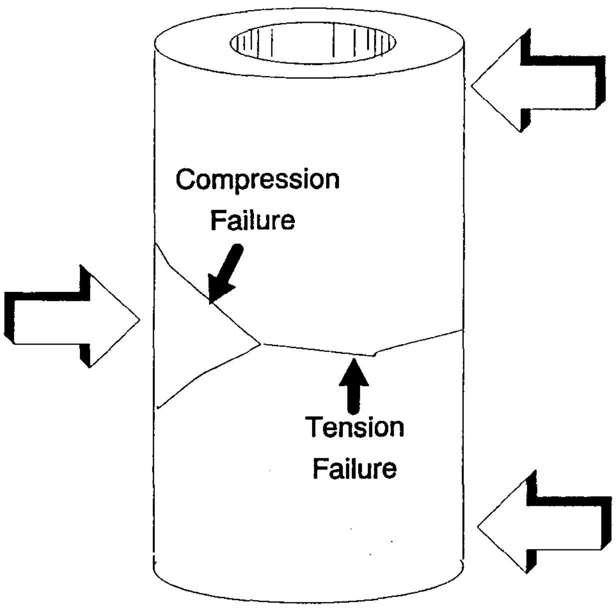


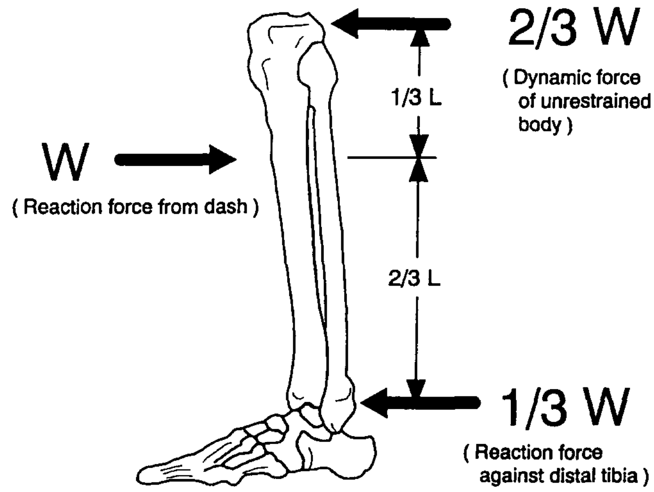
FIGURE 20. Mechanism of bone failure during 3-point bending.

VEHICLE INSPECTION

The final step is an inspection of the vehicle in which the injuries occurred. Table 10 denotes the key descriptors in relating injury to the vehicle interior.

The early inspection of an accident vehicle which has been carefully preserved from the elements and the hazards of junkyard predators is of inestimable value. Thus, the loss of a vehicle or the failure to preserve it and the valuable evidence contained within are inexcusable and calculated to prevent the optimal analysis of the accident-related injuries.

The vehicle inspection includes, first, a general survey



- To cause failure of the tibia at impact,
  $W \equiv$ Failure load of tibia = 1140 lbs. = 5078 N
- Balancing all the forces,
  The dynamic body load = 2/3 W = 3385 N
  The distal tibia load = 1/3 W = 1693 N
- To calculate body deceleration for an individual with a mass of 68 kg,
  mass (68 kg) x accel (m/sec^2) = 3385 N
  a = 49.8 m/sec^2 or 5 g's

FIGURE 21. Calculation of body g-force necessary to fail tibia in 3-point bending.

TABLE 10. ENGINEERING DESCRIPTORS

Contact related (laceration and/or fracture at point of impact)
Noncontact related (contracoup brain injury or fracture of spine from flexion and compression forces)
Objects contacted (interior and/or exterior of vehicle)
Intrusion or deformation of compartment
Interaction with restraint systems
Interaction with seats and/or compartment furniture
Force and force direction (method of force application, e.g., torsion)

to encompass artifacts caused by transport and storage. Next is the forensic documentation of body fluids, hair, and deposits of tissue or transfers of fabric or other occupant-related objects.

The exam widens to search for interior deformations which are related to (1) changes in structural elements and (2)

changes in interior furniture, e.g., instrument panel, steering wheel, mirrors, or seats. These must then be categorized as related directly or indirectly to occupant contact or simply vehicle response to the collision forces.

A knowledge of the occupant seating positions, injuries, and expected occupant kinematics (restrained or unrestrained) will suggest more likely locations for occupant contact information and help to distinguish changes not associated with occupant contact. Figure 1 shows the steps in an optimal analysis.

POTENTIAL APPLICATIONS OF INJURY RECONSTRUCTION

The conclusions of an injury reconstruction can be used in many ways. These include the following:

Evaluate Vehicle Safety Performance - The analysis of the injuries of vehicle occupants can provide an evaluation of overall vehicle crash performance. However, such analysis of a single accident is more likely to provide data on occupant interactions with the motorist compartment with special attention to interior furniture, seats, and restraint systems.

Provide Statistical Base For Comparing And Evaluating Alternative Vehicle Designs - The collection of such injury data in a uniform comprehensive manner will also provide the basis for a more compelling statistical evaluation.

Evaluate Occupant Contributions To Injury Occurrence - Occupants often bring to an accident significant pre-existing medical problems. Diseases such as osteoporosis and degenerative problems of the spine modify the response to trauma. They must be considered when human tolerance levels are factored into the injury reconstruction analysis.

Another variation is the occupant with a history of prior trauma. Whether related or not to a prior vehicular accident it is necessary to obtain all the relevant medical information. In the case of a prior vehicular accident, it may be desirable to perform a complete independent analysis of that accident.

The non-use of restraint systems can be suggested by partial or complete ejection; injuries (by nature, location and severity) which would not be expected in a restrained occupant; lack of restraint marks on the body; lack of injuries which could be attributed to restraint use (depending on the severity of the collision); contact with areas of the vehicle outside the envelope of restraint protection; other evidence of being out of position before, during or after the collision; and lack of evidence that restraint was used based on exam and analysis of use marks on webbing, hardware and seats. It is also possible to predict the effects and possible injury reduction if available restraints are used.

There is virtually no limit to the ways in which occupants can mis-use restraint systems. Some of the more common include non-use of the lap belt or upper torso belt portion of a system; introducing excessive slack in the system; and sitting in an abnormal posture, e.g., legs on instrument panel. The criteria for suggesting non-use would also apply here with the caveat that partial restraint could necessarily introduce many injury variations. This would also apply to the out of position occupant, e.g., someone restrained but leaning forward and thus using up a portion of the restraint envelope.

In the mixed restraint picture there is a combination of restrained and unrestrained occupants. Here, the unrestrained occupant may strike another occupant, accounting for unilateral or matching injuries. The unrestrained occupant may also load another occupant, increasing their effective weight and impact force.

Likewise, a careful survey should be made of unsecured cargo, particularly with unexpected injuries, e.g., a laceration to the back of the head during a frontal collision.

Determine Pre-Accident Locations Of Occupants - In particular, the identification of the driver is often an issue in accident analysis. This can often by accomplished by:

(a) Matching of injuries to specific impact areas within the vehicle.

(b) The predicted motion of an occupant for a particular delta-V and PDOF.

(c) The determination of use or non-use of restraint systems.

(d) The availability of confirming forensic evidence, e.g., blood, hair, tissue, body fluids, and transfers of fabrics and other substances.

Evaluate Effects Of Multiple Collisions - The role of multiple collisions in producing injuries is often of interest. Examples include the vehicle involved in collisions with more than one other vehicle, a vehicle which strikes a barrier and then another vehicle, or another of the many possible variations on this theme. The separate analysis of each collision using the described methodology can often determine the relative role of the various collisions in producing the described injuries.

Validate The Accident Reconstruction - Starting with known injuries and a knowledge of the forces and force directions which usually result in such injury, a retrospective analysis of an accident reconstruction can be obtained. If the reconstruction data does not match the injury causation conclusions, then a re-evaluation of the accident analysis must be considered.

Validate Claimed Injuries - The imperfect nature of a physical exam and associated laboratory studies, e.g., MRI, CT scan, myelogram, x-ray, sonogram, EEG, nerve function studies, etc., place a certain reliance on patient signs and symptoms.

On occasion, doubt is cast on the nature and severity of the patient's complaints. In such an instance, injury reconstruction can place the injuries claimed within the statistical and experimental context of what injury would be expected in the circumstances. The only caveat is that the possibility of exceptions to the rule must be carefully evaluated. Such factors as age, sex, anthropometry, pre-existing disease, unorthodox pre-impact locations, and kinematics may explain the presence of unexpected injury.

Determine Ejection vs. Containment - A frequent situation arises in which an occupant is found outside a vehicle and there is no confirmation that the occupant was removed from the vehicle. In this case, the question of ejection must be considered. Injury patterns should vary when an occupant is ejected rather than remaining inside, particularly in a rollover. Ejected occupants often have a distinctive injury pattern which may vary with the distance traveled and the terrain encountered. A careful injury reconstruction can often answer this question.

FINAL VALIDATION OPTIONS

The most complete validation of an injury reconstruction would be a full-scale crash with instrumented anthropometric dummies. Less comprehensive and less expensive tests could range from a restricted sled test down to the placement of a model of appropriate dimensions in an exemplar vehicle.

CONCLUSION

A focus on accident reconstruction may obscure the need for a causative analysis of the injuries. Such an analysis can provide valuable information that goes beyond the issues of accident causation.

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